Effects of 3 biologic dressings on healing of cutaneous wounds on the limbs of horses

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Abstract

Three biologic dressings [split-thickness allogeneic skin (STS)], allogeneic peritoneum (P), and xenogenic porcine small intestinal submucosa (PSIS)] were studied to determine their effects on bacterial proliferation, inflammatory reaction, vascularization, and overall healing and to compare the effects of these dressings with the effects of a nonbiologic dressing, a nonadherent synthetic pad (NASP). A medial wound (3 cm in diameter) and 2 lateral wounds (2 cm in diameter) were created at the junction of the proximal and middle thirds of each metacarpus and metatarsus in 5 horses. Each medial wound and the proximolateral wound received an STS, P, PSIS, or NASP dressing on day 8 after wounding. The other lateral wound received an NASP dressing. Bacterial proliferation, inflammatory reaction (histologic changes), and drhessing vascularization were evaluated 6 d after application of the dressing. Percentages of contraction and epithelialization, as well as healing time, were determined when the wounds had completely epithelialized. The practical applicability of the different dressings to equine wound management was also assessed. No significant difference was detected in the parameters evaluated among the treated wounds or between the treated and control wounds. The biologic dressings had no effect on infection, inflammatory response, or healing time. Vascularization was not identified in any of the biologic dressings. The PSIS and P dressings required numerous applications over the study period. The STS dressings are more practical than PSIS and P dressings owing to ease of application and stability. Thus, these biologic dressings offer no apparent advantage over a nonbiologic dressing for treatment of small granulating wounds.

Résumé

Trois pansements biologiques [peau allogène séparée (STS), péritoine allogène (P), et sous-muqueuse intestinale de porc xénogénique (PSIS)] ont été étudiés afin de déterminer leur influence sur la prolifération bactérienne, la réaction inflammatoire, la vascularisation et la guérison générale ainsi que de comparer les effets de ces pansements à ceux d'un pansement non-biologique, un tampon synthétique non-adhérent (NASP). Une plaie médiale (3 cm de diamètre) et 2 plaies latérales (2 cm de diamètre) ont été produites à la jonction du tiers proximal et du tiers médial de chaque métacarpe et métatarse chez 5 chevaux. Chaque plaie médiale et la plaie proximo-latérale ont reçu un pansement STS, P, PSIS ou NASP au jour 8 après induction de la plaie. L'autre plaie latérale reçue un bandage NASP. La prolifération bactérienne, la réaction inflammatoire (changements histologiques) et la vascularisation du pansement ont été évaluées 6 j après l'application du pansement. Les pourcentages de contraction et d'épithélialisation, de même que le temps de guérison, ont été déterminés lorsque les blessures étaient complètement épithélialisées. L'applicabilité pratique des différents pansements pour soigner les plaies chez les chevaux a aussi été évaluée. Aucune différence significative n'a été détectée parmi les paramètres évalués entre les plaies traitées ou entre les plaies traitées et les plaies témoins. Les pansements biologiques n'avaient aucun effet sur la présence d'infection, la réponse inflammatoire ou le temps de guérison. Aucune vascularisation ne fut détectée chez les pansements biologiques. Les pansements PSIS et P ont nécessité de nombreuses applications durant la période d'essai. Les pansements STS sont plus pratiques que les pansements PSIS et P étant donné leur facilité d'application et leur stabilité. Ainsi, les pansements biologiques n'offrent pas d'avantages apparents sur les pansements non-biologiques pour le traitement des petites plaies de granulation.

(Traduit par Docteur Serge Messier)

Introduction

Horses often suffer cutaneous wounds on the distal portion of the limb that are difficult or impossible to close and must heal by 2nd intention. Ideally, a wound on the distal portion of a limb that cannot be closed primarily should be covered with a dressing that controls bacterial proliferation, does not induce excessive inflammation (antigenic reaction), and promotes contraction and epithelialization, 2 key features of 2nd-intention healing.

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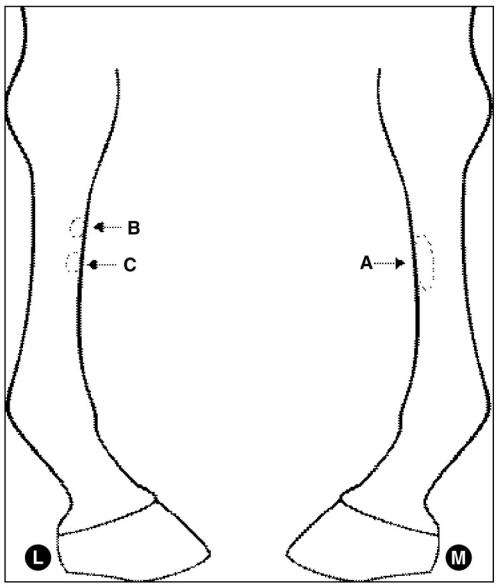

Figure 1. Surgically created wounds. L — lateral side; M — medial side; B — proximolateral wound; C — distolateral wound; A — dorsomedial wound.

Biologic dressings (those derived from tissue, such as skin or amnion) reportedly promote wound healing by retarding the formation of exuberant granulation tissue, by providing and maintaining a moist environment that is conducive to regeneration and migration of epithelial cells, and by acting as a bacterial barrier to protect the wound from infection (1–3). Biologic dressings also induce a mild inflammatory response, which has been reported to have a beneficial effect on healing (4). Additionally, the occlusive, adherent nature of biologic dressings is reported to markedly decrease pain associated with open wounds (5). The optimal biologic dressing is a cutaneous autograft, but the limited supply of autogenous skin and the morbidity and expense involved in obtaining an autograft have stimulated interest in the use of cutaneous allografts and other biologic dressings in human medicine (6,7). Some types of biologic dressings (cutaneous allografts) may adhere firmly to the wound by vascular connections, whereas non-biologic dressings bind to the wound only with fibrin. The firm, vascular adherence of biologic dressings may be responsible for many of the qualities that these dressings impart to healing of wounds (1,2,6–8). Since the middle of the last century, cutaneous allografts have been used extensively as biologic dressings to temporarily cover large wounds on humans (9,10). We found no reports, however, describing the use of cutaneous allografts on wounds of horses.

Because of the short supply of cutaneous allografts to cover wounds of humans, other biologic dressings have been used extensively (5,11,12). Processed collagen, usually extracted from submucosa of the small intestine, has been used as a xenogenic wound dressing in multiple species (2,8,12,13). The collagen becomes incorporated in the wound and reportedly performs as a scaffold that promotes adhesion and migration of fibroblasts and keratinocytes, thus shortening the healing process (2,14). Porcine small intestinal submucosa (PSIS) and processed collagen dressings (primarily composed of bovine collagen) have been used to treat wounds in horses and dogs (15–19). Processed bovine collagen applied to wounds of horses has been reported to significantly increase the degree of inflammation (17) but did not increase epithelialization or contraction of wounds (17,18). Dressings of hydrolyzed bovine collagen were reported to stimulate wound epithelialization on dogs (19).

Equine peritoneum was evaluated as a biologic dressing because peritoneum is a readily available allogeneic source of connective tissue that is rich in collagen (20). Additionally, the biologic nature of the peritoneum (a thin layer of loose connective tissue) may permit vascularization of the dressing. These properties suggest that equine peritoneum as a biologic dressing may enhance wound healing.

The objectives of the study reported here were to evaluate the effects of 3 biologic dressings (split-thickness allogeneic skin, allogeneic peritoneum, and xenogenic PSIS) on bacterial proliferation, inflammatory (immunogenic) reaction, and healing in wounds on the distal portion of limbs of horses. Vascularization of the different biologic dressings and practicality of their use were also evaluated. The effects of these dressings were compared with the effects of a commonly used, commercial, nonbiologic dressing.

Materials and methods

Animals

Five adult horses (3 mares and 2 geldings), 8 to 17 years old and weighing 450 to 650 kg, were used in the study. Auburn University's Institutional Animal Care and Use Committee approved all procedures used in the study.

Creating the wounds

The horses were placed under general anesthesia, and a full-thickness, 3-cm-diameter, circular piece of skin was excised from the medial aspect of the junction of the proximal and middle thirds of each metacarpus and metatarsus (day 0). Additionally, 2 circular sections of skin 2 cm in diameter and 2 cm apart in proximodistal orientation were excised from the lateral aspect at the junction of the proximal and middle thirds of each metacarpus and metatarsus (Figure 1). The percentages of wound contraction and of epithelialization of the healed wound, as well as the time to healing, were evaluated in the 3-cm medial wounds. The 2-cm lateral wounds were created to allow histologic and microbiologic evaluation of wounds at 8 and 14 d after wounding without disrupting the healing process of the 3-cm dorsomedial wound. All horses were treated per os with phenylbutazone (Phenylzone paste; Shering–Plough Animal Health, Union, New Jersey, USA), 4.4 mg/kg once a day the morning of surgery and the day after surgery.

All wounds were initially covered with a sterile, nonadherent, synthetic pad (NASP) (Release Non-adhering Pad; Johnson & Johnson, Arlington, Texas, USA) impregnated with 500 mg of a cefotaxime solution (Claforan; Hoechst–Rousell, Kansas City, Missouri, USA). The pad was secured with sterile elastic gauze (Conform; Kendall Healthcare Products Company, Mansfield, Massachusetts, USA). An absorbent cotton pad, 30 × 30 cm (Redi Roll; The Franklin Williams Company, Lexington, Kentucky, USA),

was applied to each metacarpus and metatarsus and secured with an elastic adhesive bandage (Vetwrap; 3M Animal Care Products, St. Paul, Minnesota, USA). The antibiotic solution was reapplied during bandage changes on days 2, 4, and 6. At day 8, the wounds were dressed with either a biologic dressing or NASP. The bandages were applied as described above to cover the biologic dressings or the NASP and changed every other day until the wounds were completely epithelialized.

Obtaining the dressings

Split-thickness skin (STS) and peritoneum (P) were collected aseptically, within 4 h after donor horses (2 mares and 3 geldings, 4 to 20 years old, weighing 450 to 600 kg) were humanely euthanized for reasons not related to this study.

Allogeneic STS grafts (approximately 0.2 to 0.3 mm thick) were collected from the ventral abdomen by means of a handheld dermatome (Watson Knife; Padget Instruments, Kansas City, Missouri, USA). Peritoneum was harvested via a ventral midline incision from the umbilicus to the xiphoid cartilage. With blunt and sharp dissection, 3 or 4 sheets of peritoneum (approximately 18 × 18 cm) were carefully dissected from the fat of the abdominal wall and cut into sections (approximately 8 × 8 cm).

The skin or peritoneum was placed on gauze and rolled before placement in a cylinder containing 9 parts sterile tissue-culture medium (McCoy's 5A medium; Invitrogen, Baltimore, Maryland, USA) and 1 part gamma-globulin-free equine serum (Gibco Laboratories, Grand Island, New York, USA). The dressings were refrigerated at 4°C for 5 to 14 d before being applied to the wounds.

Sterile sheets of processed collagen membrane (Vet BioSISt; Cook Veterinary Products, Bloomington, Indiana, USA) derived from PSIS were supplied in individual packs by the manufacturer and stored at room temperature.

Applying the dressings

Treatment wounds (the small proximolateral wound and the large medial wound of 3 limbs) received a biologic dressing on day 8 after wounding. Fenestrations 2 mm in diameter were made in each STS, P, and PSIS dressing before application: 9 for the small lateral wounds and 15 for the medial wounds.

Dressings were placed on the wound so that the fenestrated section contacted the wound. The portion of the dressing that overlapped the margin of the wound was fixed to the margin with cyanoacrylate glue (Super Glue; American Glue Corporation, St. Paul, Minnesota, USA). The PSIS dressings were applied in accordance with the manufacturer's recommendations.

A NASP was placed over the biologic dressing, and an outer bandage was applied as described earlier. The limbs with the control wounds were bandaged similarly to the limbs with the wounds that received a biologic dressing. All wounds were rebandaged every other day until they were completely epithelialized.

Biologic dressings were assessed every other day (at each bandage change) and were replaced if they disintegrated or were not firmly adhered to the wound. The NASP was changed every other day during the study.

Study groups

The 4 limbs of each horse were randomly assigned 1 of the 3 biologic dressings and the control dressing; each limb received only 1 type of dressing. The medial wound and the proximolateral wound of each limb received an STS, P, PSIS, or NASP dressing. The distolateral wound of each limb served as a control wound and received only an NASP.

Subjective observations

At every bandage change, the wounds were observed grossly for antigenic reaction: graft rejection associated with edema, vesiculation of the wound, maceration of the biologic dressing, or marked accumulation of exudate (21). The wounds were also observed for formation of exuberant granulation tissue (higher than the wound edges) during the study.

Evaluation parameters

Microbiology — Calcium alginate swabs for quantitative bacterial isolation were obtained from the distolateral wound on day 8 after wounding and from the proximolateral wound on day 6, after application of the dressings (day 14 after wounding). The samples were incubated at 35°C for 18 to 24 h in a brain-heart infusion agar growth medium (Difco, Kansas City, Missouri, USA). A total aerobic, heterotrophic plate count was performed for each of the samples.

Histologic evaluation — Biopsy specimens were taken as follows to evaluate inflammatory reaction and vascularization: distolateral wound (day 8 after wounding), proximolateral wound (day 14 after wounding, 6 d after dressing application), and medial wound (15 d after complete epithelialization). The specimens were placed in 10% formalin, routinely processed, and stained with hematoxylin and eosin. The specimens of the wounds that received PSIS dressings were also stained with trichrome to more clearly identify collagen from the dressing. Approximately 10 selected 400 × fields were examined for each specimen.

The following histologic features were examined and quantified: the concentration of cellular infiltrates (neutrophils, eosinophils, lymphocytes, plasma cells, macrophages, and mast cells) and the degree of edema, acute and chronic hemorrhage, necrosis, fibroblastic proliferation, collagen density, and neovascularization. Features were scored from 0 to 3 (0 — normal; 1 — mild change; 2 — moderate change; 3 — marked change).

Planimetry — The cutaneous perimeter of the large, medial wound was traced onto a sterile, transparent polyethylene sheet 2 d after wounding and every other day until healing (complete wound epithelialization). Using these tracings and a digitizing program (Sigma Scan; Scientific Measurements System, Jandel Scientific, Corte Madera, California, USA), we evaluated the beginning total wound area (day 8, before placing the dressings) and the percentages of wound contraction and epithelialization after the wounds had healed. The areas used to calculate these percentages were the total wound area (the area of epithelialization and the area of granulation) on day 8 compared with the area of epithelialized wound on the day the wound was considered completely epithelialized. These data were used to compare the percentages of wound contraction and epithelialization among the 4 study groups.

Table I. Healing of equine limb wounds in the 4 treatment groups

	Mean values ± standard deviation			
Healing variables	NASP (n = 5)	STS (n = 5)	PSIS (n = 5)	P (n = 5)
Days to healing	34.8 ± 2.28	38.8 ± 5.59	35.2 ± 2.28	38.8 ± 5.76
Wound size (cm^2)				
Initially	7.72 ± 1.59	8.56 ± 0.90	8.44 ± 1.46	7.88 ± 1.07
At 8 d, before dressing	9.61 ± 1.13	10.91 ± 2.30	11.19 ± 2.90	9.19 ± 0.88
Final scar size (cm^2)	2.77 ± 1.30	2.97 ± 1.13	2.74 ± 1.60	2.44 ± 1.47
Final epithelialization (%)	33.81 ± 12.6	33.21 ± 9.8	27.55 ± 12.1	29.79 ± 18.0
Final contraction (%)	57.7 ± 10.1	67.86 ± 7.7	67.5 ± 10.5	62.6 ± 9.0

NASP — nonadherent synthetic pad; STS — split-thickness allogeneic skin; PSIS — porcine small intestinal submucosa; P — allogeneic peritoneum

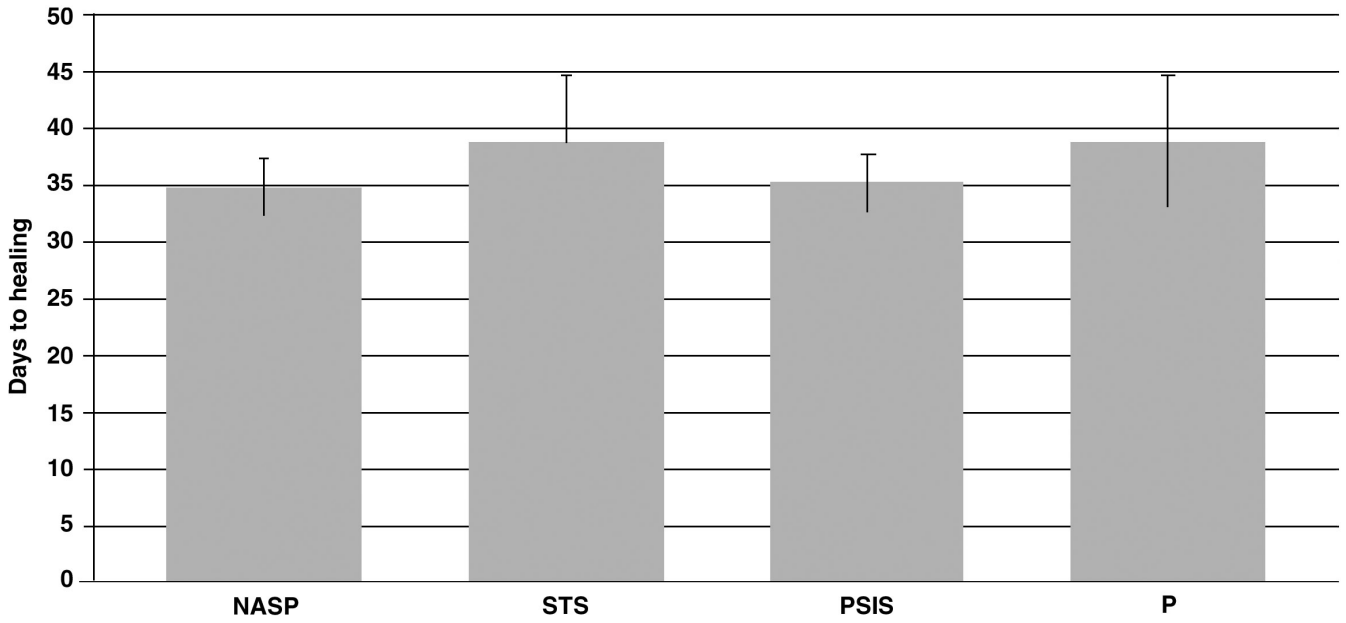

Figure 2. Mean healing time by treatment type, 5 subjects per group. Bars represent standard deviation. NASP — nonadherent synthetic pad; STS — split-thickness allogeneic skin; PSIS — porcine small intestinal submucosa; P — allogeneic peritoneum.

Healing time — The time between the creation of the wound and the day that each wound was covered with epithelium was evaluated to compare the time to healing among the 4 study groups.

Statistical analysis — Scores for each histologic variable were analyzed with the use of ranked data and a repeated-measures analysis of variance. This is equivalent to a repeated-measures Kruskal–Wallis test. The treatments on each horse were entered into the repeated-measures design to adjust for dependency on horse (SAS Institute, Cary, North Carolina, USA). Percentages of contraction and time to total healing were analyzed with the use of Sigma Stat, Version 2.03 (SPSS, Chicago, Illinois, USA). For all statistical tests, significance was set at $P < 0.05$.

Results

Subjective observations

Signs of mild inflammation (redness, swelling, and discomfort during palpation) were observed immediately after wounding and after application of the biologic dressings. However, these signs subsided within a week of wounding and within a week after the biologic dressings had been applied. No wound displayed gross evidence of strong antigenic reaction to any of the 3 biologic dressings (graft rejection associated with edema, vesiculation of the wound, maceration of the biologic dressing, or marked accumulation of exudate). No wound (treated or control) displayed exuberant granulation tissue. For all wounds, epithelium advanced at a greater rate from the distal aspect of the wound than from the proximal aspect.

From observation of the overlying NASP dressings, wounds dressed with PSIS exuded more fluid than did the other wounds from the time the dressings were applied until the wounds were nearly epithelialized. Little fluid was observed on the surface of the NASP applied to the wounds that received the STS dressing. During the bandage changes, we observed that the "nonadhering" pad adhered more tightly to the wounds that received the biologic dressings than to the control wounds, especially during the first 10 d after the wounds received the dressing. The NASP adhered more firmly to the PSIS and P dressings than to the STS dressings and the

Table II. Histologic scores for all wounds, without regard to treatment type

Histologic parameter	Mean score[a]		
	8 d after wounding (n = 20)	14 d after wounding (n = 20)	15 d after complete epithelialization (n = 20)
Neutrophils	2.50[b]	2.15[b]	0.90[c]
Lymphocytes	1.75[b]	1.35[b]	0.55[c]
Fibroblasts	1.40[b]	1.95[b,c]	0.70[b,d]
Collagen density	1.40	1.85	2.05
Edema	0.25[b]	0.75[b,c]	0.15[b,d]
Neovascularization	1.70[b]	2.15[b]	0.75[c]

[a] 0 — normal; 1 — mild change; 2 — moderate change; 3 — marked change. Significant ($P < 0.05$) differences exist between values in a row with different superscripts (b, c, or d). Rows with no superscripts have no significant differences between the groups

control wounds. Owing to their fragility, the PSIS and P dressings were more difficult to apply than the STS dressings.

As the wounds healed, the STS and P dressings appeared to become progressively desiccated from the periphery toward the centre of the wound; this was observed at the same time that epithelium was proliferating beneath the dressing towards the centre of the wound.

Dressings were replaced a mean of 1.6 times per horse over 30 d for STS, 2.8 times over 27 d for PSIS, and 3 times over 30 d for P. The STS and P dressings sloughed from the wound when the wound was completely epithelialized. The PSIS dressings were incorporated into the nonepithelialized portion of the wound.

Evaluation parameters

Planimetry — The mean percentages of wound contraction and epithelialization and the wound size at the beginning and at the end of the study did not significantly differ between the treatment groups (Table I).

Healing time — There were no significant differences in healing time among the treated wounds or between the treated and control wounds (Table I, Figure 2), nor were there differences in healing time between wounds on hindlimbs and wounds on forelimbs.

Histologic evaluation — There was no significant difference between the treatment groups, at any point examined, in any of the scores for inflammation. The only significant findings related to inflammation were higher scores for neutrophils, lymphocytes, fibroblasts, edema, and neovascularization at 8 and 14 d after wounding when compared with 15 d after complete epithelialization (Table II). The scores for collagen density in the wounds increased at each evaluation point (8 and 14 d after wounding and 15 d after epithelialization) for the control and treated wounds but did not differ significantly among the treatment groups at any time of evaluation. The trichrome-stained sections of biopsies of wounds dressed with PSIS revealed incorporation of collagen dressing into the wound. Blood vessels penetrated the fibrin layer formed between the wound and the biologic dressings, but vessels were not observed penetrating any dressing at any time of evaluation.

Microbiology — Bacterial numbers did not differ among the treatment groups or between the treated and control wounds. Bacterial numbers at 8 d, before dressing application (with antibiotic treatment), did not differ from those 6 d after dressing application (with no antibiotic treatment). Multiple colonies of gram-positive bacteria, considered to be normal skin flora or environmental contaminants, were cultured from swabs of 8 of the 20 wounds taken before the biologic dressings were applied at day 8. At day 14, bacteria considered to be normal skin flora, environmental contaminants, or a natural replication of bacteria in the incubation medium were cultured from 7 of the 20 wounds. There was no association between bacterial concentration and type of dressing.

Discussion

There were unique findings in this study. Whereas a previous study reported healing to be slower for wounds on the distal aspect of the hindlimbs of horses than for wounds on the distal aspect of the forelimbs (17,22), we detected no difference in the times to healing between the wounds on the hindlimbs compared with those on the forelimbs.

In contrast to 3 previous equine studies of similar-sized wounds of the distal limb (17,18,23), we did not observe exuberant granulation tissue in any wound. However, another equine study of similar wounds also found no exuberant granulation tissue (24). The 2 studies without exuberant granulation tissue had more frequent bandage changes than the studies in which exuberant granulation tissue developed. As the wounds in our study healed to full epithelialization much more rapidly than smaller wounds in a recent study in which the wounds were not bandaged — in approximately 35 to 38 d in our study versus approximately 95 d in the study of Berry and Sullins (23) — we do not feel that the bandages themselves are the problem. We agree with the conclusion of Berry and Sullins that the decreased amount of granulation tissue associated with more frequent bandage changes is due to more frequent removal of excess exudate, which has been reported to induce the production of granulation tissue (25,26). Thus, as a bandage provides a moist environment, which has been reported to favour epithelialization (1,21), we feel that it is important to keep the wounds bandaged but also to change the bandages frequently.

The finding of more rapid epithelialization of the distal margin of the wounds than of the proximal margin has been previously reported in dogs (27) and is related to the direction of the hair and the angle of the hair follicles in the skin (28).

The value of biologic dressings for equine wound management is dependent on both the influence of the dressing on wound healing and the practicality of application of the dressing to the wound surfaces. Although 2 of the main features of wound healing are the speed of contraction and epithelialization, these processes are

affected by numerous other factors, including superficial wound infection, degree of inflammation, and production of exuberant granulation tissue (26,29). Although other commercial biologic dressings have been reported to decrease wound bacterial numbers (1,3), we were also interested in determining if there were any positive or deleterious effects on wound bacterial growth of the application of the allogeneic tissue dressings, which were stored in growth medium and might be a nidus for bacterial growth (2,7). We noted no effect on bacterial growth of application of any of the biologic dressings to the wounds.

Wound inflammation has been reported to increase in human wounds with cutaneous allografts (9) and in equine wounds covered with a biologic bandage containing bovine collagen (17). The observed absence of such an increase with any of the biologic dressings that we tested may be due to several factors. First, one reported cause of a mild or strong allergic inflammatory response to cutaneous types of biologic dressings is vascularization of the dressing (3,9). As the STS dressings did not exhibit histologic evidence of vascularization, this potential cause of inflammation may not have been present. Second, the lack of infection in all wounds may have contributed to a low level of inflammatory cell influx.

Wound contraction, a vital component of wound healing, has been previously reported to be decreased with the use of both cutaneous grafts in pigs and PSIS in rats (30,31). However, in our study, the biologic dressings had no inhibiting effect on contraction (the percentage of contraction was similar in the treated and control wounds). This disparity in results may be due to a species difference but may also be due to the fact that the wounds in this study were grafted at 8 d after wounding (when the wounds were granulating), whereas the dressings were applied to fresh wounds in the 2 studies in laboratory species (30,31). As granulating equine wounds have been previously reported to undergo a higher rate of contraction than fresh wounds, there may be less of an inhibitory effect of the biologic bandages on contraction once an active contraction process has commenced (32).

Epithelialization, another critical component and marker of wound healing, has been reported to be enhanced in wounds in which a biologic dressing containing processed collagen was used in laboratory rodents (31). Additionally, wounds of dogs that received hydrolyzed bovine collagen dressings reportedly exhibited an increase in the percentage of epithelialization (19). However, as with previous studies using processed bovine collagen membranes or collagen gel on wounds in horses (17,18), we found no effect of a commercial processed porcine collagen dressing (PSIS) or allogeneic sources of collagen (STS and P) on wound epithelialization.

The difference in practicality of application of the 3 biologic dressings to equine wounds was marked in our study. The fragility of the dressings played an important role in the management of the wounds. The PSIS and P dressings were more fragile than the STS dressings and were often partially disintegrated at the time of bandage change. Consequently, wounds dressed with either PSIS or P dressings required more frequent replacement of the dressing (2.8 replacements per horse for wounds dressed with PSIS in a 27-d period and 3 replacements per horse for wounds dressed with P in 30 d) than did the wounds dressed with the cutaneous STS dressing (1.6 replacements per horse in 30 d).

Wounds dressed with PSIS were more moist than the control wounds and more moist than the wounds treated with STS or P dressings. The hydrophilic nature of hydrolyzed bovine collagen powder applied to wounds of dogs was observed in a previous study (19). It is possible that PSIS has a similar hydrophilic nature. The moisture observed with PSIS may have led to the disintegration of the dressings.

Overall, STS was easier to apply than PSIS and P, easier to collect in larger quantities than P, cost less than PSIS, and was more stable than PSIS or P.

We agree with the conclusions of a recent paper that, although researchers tend to make small wounds for wound-study experiments for humane reasons, small wounds may not have the same healing characteristics as larger wounds (23). Therefore, the small wounds used in our study may not allow for detection of treatment effects of the different dressings; that is, the small wounds may heal similarly, regardless of treatment. Larger wounds that more closely resemble those seen in clinical cases may be a more applicable model for future equine wound-healing studies.

In summary, there was no advantage of application of any of the 3 biologic dressings compared with a nonadherent synthetic pad for the treatment of small, granulating wounds. However, owing to the attributes of STS found in our study and the possible lack of similarity of healing of small experimental wounds when compared with the larger distal limb wounds observed in clinical equine cases, further research is indicated to assess the effects of STS dressings on large distal limb wounds of horses. In the interests of animal welfare, such a study should be a controlled clinical study.

Acknowledgments

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